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CALIBRATION OF THE SSJ/3 SENSOR ON THE DMSP SATELLITES.(U)

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F19628-76-C-0039

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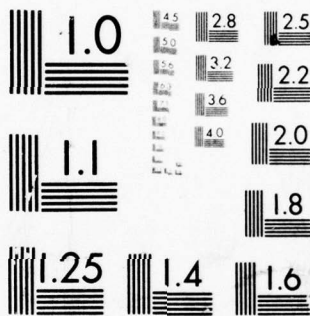
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CALIBRATION OF THE SSJ/3 SENSOR ON THE DMSP SATELLITES

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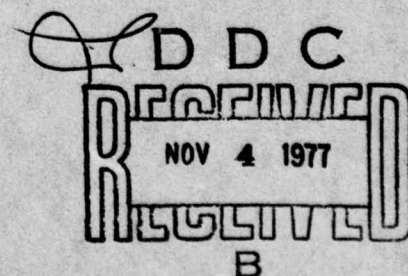
SEPTEMBER 1977

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

19. REPORT DOCUMENTATION PAGE		READ INSTRUCTIONS BEFORE COMPLETING FORM	
1. REPORT NUMBER	2. GOVT ACCESSION NO.	3. RECIPIENT'S CATALOG NUMBER	
18 AFGL TR-77-0202			
4. TITLE (and Subtitle)		5. TYPE OF REPORT & PERIOD COVERED	
6 CALIBRATION OF THE SSJ/3 SENSOR ON THE DMSP SATELLITES.		14 SCIENTIFIC 18-2 01APR77 - 01SEP77	
7. AUTHOR		6. PERFORMING ORG. REPORT NUMBER	
10 ALAN/HUBER* A.L./BESSE JOHN/PANTAZIS P.L./ROTHWELL			
8. CONTRACT OR GRANT NUMBER(s)		15 F19628-76-C-0039	
9. PERFORMING ORGANIZATION NAME AND ADDRESS		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBER	
EMMANUEL COLLEGE 400 THE FENWAY BOSTON MA 02115		16 61102F 17 G1 2311G102	
11. CONTROLLING OFFICE NAME AND ADDRESS		12. REPORT DATE	
AIR FORCE GEOPHYSICS LABORATORY HANSCOM AFB MA 01731 CONTRACT MONITOR: ROBERT C. FILZ (PHG)		11 SEP 1977	
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		13. NUMBER OF PAGES	
9 Rept. for 1 Apr - 1 Sep 77		42	
15. SECURITY CLASS. (of this report)		15a. DECLASSIFICATION DOWNGRADING SCHEDULE	
UNCLASSIFIED			
16. DISTRIBUTION STATEMENT (for this Report)			
A - APPROVED FOR PUBLIC RELEASE; DISTRIBUTION UNLIMITED			
12 43p.			
17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)			
18. SUPPLEMENTARY NOTES			
*PHYSICS RESEARCH DIVISION, EMMANUEL COLLEGE			
19. KEY WORDS (Continue on reverse side if necessary and identify by block number)			
SSJ/3 SENSOR MONTE CARLO CODE CHANNELTRON ELECTROSTATIC ANALYZER			
20. ABSTRACT (Continue on reverse side if necessary and identify by block number)			
The SSJ/3 sensor is designed to measure electrons from 50 eV to 20 keV. This is accomplished by using two head assemblies with common signal processing and voltage sources. The low-energy head assembly selects 50.0 to 1,000 eV electrons over eight channels with a normalization factor $H = 4.3 \times 10^{-5} \text{ cm}^2$ ster. The high-energy assembly similarly selects 1.00 to			

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20.0 keV electrons over eight channels with an H-factor equal to $1.30 \times 10^{-5} \text{ cm}^2\text{-ster.}$

Energy resolution is approximately 10% for an isotropic incident flux. An electron beam was used to determine angular and energy response. These measurements were compared with results from a Monte-Carlo computer code and approximate analytic methods to determine the final normalizations.

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FIGURE CAPTIONS

- Figure 1. The SSJ/3 instrument and associated electronic boards. The rectangular slits are entrance apertures for electrons. Behind the small circular hole is a UV detector that causes the channeltron acceleration voltage to be turned off when viewing the sun.
(17)
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(18)
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(27)

I. INTRODUCTION

The calibration of the SSJ/3 sensor was carried out using both experimental and theoretical techniques. Experimental measurements were compared with predictions from a Monte Carlo particle tracing code and from analytic approximations.

In Section II instrument design is discussed. Section III described techniques used in calibration while Section IV describes the logic used to obtain the final normalization values.

II. INSTRUMENT DESIGN

Introduction. The SSJ/3 instrument package is shown in Figures 1 and 2. Figure 1 shows the instrument case and the associated electronic boards. The apertures on the case are directly in front of the particle collimators that are shown in the bottom of Figure 2. Behind the collimators are curved cylindrical plates. The plate separation and the applied voltage determine the energy band of the transmitted electrons. The electrons, after passing through the exit collimator, are detected by the C-shaped Channeltron Electron Multiplier detectors that are also shown in Figure 2.

Head Assembly. Electrostatic analyzers (ESA's) select charged particles by applying a voltage between two concentric plates. The SSJ/3 instrument uses two sets of cylindrical concentric plates as shown in Figure 2. Charged particles of the proper sign and energy have trajectories that are almost parallel to the plate surfaces. Particles of greater or lesser energy impinge on the plate surfaces. The mean energy E can be easily derived by requiring a balance between electrostatic and centrifugal accelerations. For plates of radii r_1 and r_2 ($r_2 > r_1$) and an applied voltage difference of V , E is given by

$$E = \frac{eV}{2 \ln(r_2/r_1)} \quad (1)$$

If V is fixed then the detected energy is determined by the ratio of r_2 to r_1 . This explains the larger plate separation, ΔR , for the lower energy detector assembly as tabulated in Figure 3. The sector angle of the plates and their separations, together with aperture and exit slits, determine the

transmission efficiency. Additional baffles are placed in the aperture assembly to eliminate sunlight (UV) scatter into the detectors.

Behind the exit aperture, the two channeltrons are mounted as shown in the lower righthand corner of Figure 2. Electrons impinging on the cone-shaped area produce secondaries which cascade through the channeltron producing a detectable pulse at the end. This pulse is then processed by the instrument's internal electronics. Channeltron operating lifetime is extended by shutting off the accelerating potential whenever the instrument is looking at the sun. This is done by a small phototransistor mounted adjacent to the instrument apertures. See Figure 1. In Figure 3 is a schematic representation of the SSJ/3 head assemblies and gives the relevant dimensional values.

Electronic Logic. Figure 4 shows the electronic logic. The channeltron outputs (DET L and DET H) are amplified and then counted in nine-bit logarithmic counters. A complete 16-channel energy spectrum is read out every second. Appendix A describes in detail the conversion of the logarithmic counter to decimal form. The same programmable power supply is used for biasing both sets of plates. The voltage difference for each set of plates is obtained by applying $\pm V/2$ to each plate.

III. TECHNIQUES USED IN CALIBRATION

Experimental. Experimental calibrations were made using accelerated electrons from a Tritium source. After acceleration by an applied voltage, the beam was collimated so that a mono-energetic, unidirectional source was incident on the instrument apertures. A turntable enclosed in a vacuum system provided mobility for angular response measurements. The beam was found to have an energy dispersion which was negligible in comparison with the instrument's response. By changing the applied voltage various energies could be selected.

Theoretical Approximations. Geometric considerations lead to the following results: 1) If a and b are the heights of the entrance and exit apertures of the collimator and ℓ is the separation then between them such that $\ell \gg a + b$, then the angular resolution, $\Delta\theta$, is to a good approximation given by $\Delta\theta \approx (a + b)/\ell$. This approximation works well for the direction parallel to the plates, but not for the orthogonal component. 2) The geometric factor ($\text{cm}^2\text{-sec}$) for a long rectangular collimator is approximated by

$$G = \frac{A_1 \times A_2}{\ell^2}$$

A_1 = area of collimator entrance aperture

A_2 = area of collimator exit aperture

ℓ = distance between apertures

This formula provides a rapid means of obtaining a "ballpark" estimate for the geometric factor of a rectangular collimator. We used, however, the exact expression given in Appendix B in deriving our final results.

Monte Carlo Program. In Appendix C is a listing of the Monte Carlo computer code used to analyze instrument response. The basic idea is to trace electrons through the instrument to determine if they hit the channeltron. In this manner the

effect of design can immediately be recognized.

Input data includes aperture geometry, plate radii, arc length of plates, plate voltage, channeltron size, and the position of the aperture and channeltrons relative to the plates. A retarding potential can also be inputted which impedes secondary electrons produced in the plates from hitting the channeltrons. Provision has also been made to examine elastic scattering off the plate surfaces. This feature will not be used.

Let us now consider an isotropic flux, J , incident on the outside aperture. The number of incident particles per unit area is given by

$$dN = J \sin\theta \cos\theta \, d\theta \quad (1)$$

or if R is a random number over the interval 0-1 then the relation

$$\theta = \frac{1}{2} \cos^{-1}(1-2R) \quad (2)$$

generates the appropriate angular distribution of incident particles.

As a test we generated 6×10^5 particles through the high-energy collimator using equation (2). The theoretically calculated geometric factor for this collimator (1.8 cm high x 0.2 cm wide x 1.15 cm long) is $0.0622 \text{ cm}^2/\text{sr}$ (Appendix B). The "measured" geometrical factor using particle tracing was found to be $0.0624 \text{ cm}^2/\text{sr}$ which agrees with the theoretical value to within 0.32%. This result confirms that the computer code was properly simulating an incident isotropic flux through the collimator.

IV. RESULTS

The Method. Instrument calibration is determined by comparing the predicted (Monte Carlo) response curves with the measured ones. First, we look at the energy resolution for a normally incident beam. Then angular response is examined in directions parallel and perpendicular to the plates. After showing substantial agreement with experimental data, the Monte Carlo code is used to calculate the final normalizations for an incident, isotropic flux. Comparisons are made with results from approximate analytic techniques. Channeltron detection efficiency as a function of incident electron energy is also discussed and included.

Throughout this section we use energy channels 8 and 9 to determine the response properties of the two head assemblies.

Energy Resolution. In Figure 5 the Monte-Carlo and experimental results are shown for a normally incident electron beam. The beam energy was systematically scanned across the channel to obtain the energy response curve. It is seen from Figure 5 that the Monte Carlo and experimental results are in excellent agreement.

Angular Response. Figure 6 shows the angular response (α) of the high energy plates in the plane perpendicular to the plates (R-plane). In this case the measured resolution is somewhat wider than that predicted by Monte Carlo. This effect is probably due to scattering off the plate surface. Figure 7 shows a similar response curve for the low-energy plates. Observe that there are fewer measured particles than predicted at large positive angles. This effect is probably from fringe electric field resulting from larger plate separation. See Figure 2. The triangular shape of the theoretical response curve indicates that the front collimator

is the dominant determinant of the angular response.

Now we look at the angular response (β) in the plane parallel to the plate surfaces. All angular response curves are determined at the central (peak) channel energy. Figure 8 shows the appropriate curves for the high energy (narrowly separated) plates. Note that while the resolution is in excellent agreement, there is a systematic shift of about 2.5° . Because the resolution is about 8.0° , we do not consider this error as being serious. Figure 9 shows similar curves for the low energy (widely separated) plates. Here there is also a systematic shift of about 1.25° . Note that for both angular scans the measured resolutions for the low energy plates are less than the predicted ones. This is opposite to what one would normally expect and indicates a slight systematic error.

Final Normalizations. The final normalizations were determined using the Monte Carlo program. As described previously, an isotropic flux is taken incident on the front aperture. One thousand electrons are traced through the plates at each energy. Figure 10 and 11 show the results for channels 8 and 9 respectively. The ordinate represents the percentage of electrons that are detected after leaving the collimator (i.e. the transmission efficiency through the plates). The integral of this curve times the aperture G-factor gives the final normalizations.

For an incident flux J the count rate (CR) is given by

$$JG = CR$$

where G is the normalization factor in $\text{cm}^2/\text{sr}/\text{ev}$. The G-factor can be approximated by

$$G \approx A \Omega \Delta E$$

A = area of entrance aperture

Ω = acceptance solid-angle

E = energy bandwidth

Dividing by the center energy E we have

$$H = G/E \approx A \Omega \frac{\Delta E}{E}.$$

Now since A, Ω and $\Delta E/E$ are constant for each set of plates, then this one number H characterizes the normalization for all channels. For the high-energy (narrowly separated plates) channels $H = 1.30 \times 10^{-4} \text{ cm}^2/\text{sr}$. For the low-energy (widely-separated plates) $H = 4.3 \times 10^{-5} \text{ cm}^2/\text{sr}$.

We now compare this result with an approximate analytic approach. In this approach it is assumed that the energy and angular response curves are independent gaussian distributions. The final normalization is the integral product of these distributions. The result is

$$H = 1.20 A \epsilon R_0 \Delta\alpha\Delta\beta$$

where A is the aperture area, R_0 is the channeltron detection efficiency (at $E \sim 1 \text{ keV}$, $\epsilon = 1$), R_0 is $\Delta E/E$, $\Delta\alpha$ and $\Delta\beta$ are the FWHM (full-width half maximum) of the angular response curves.

Using the measured results tabulated in Table 1, this approximation gives us $H = 6.8 \times 10^{-5} \text{ cm}^2/\text{sr}$ for the high energy plates and $H = 5.55 \times 10^{-5} \text{ cm}^2/\text{sr}$ for the low energy plates. Note, however, that energy and angular resolutions are not independent for this particular electrostatic analyzer, contrary to the assumptions in the approximate approach.

A wide collimator allows more electrons at various energies to reach the channeltrons. A narrow collimator allows fewer electrons to reach the detectors over a narrower energy bandwidth. This effect is seen by comparing Figure 5 with Figures 10 and 11. The energy resolution of the high-energy plates is 2.3 times greater for an isotropic flux than for a normally incident flux. For the low energy plates it is 1.5 times greater. We interpret this difference to be due to the collimator in front of the high energy plates having a G-factor 16 times that of the one in front of the low-energy plates. It is for this reason we consider the Monte Carlo normalization as more closely reflecting realistic fluxes.

The final normalizatin values for each energy channel as given in Table 2. Dividing the count rate by the approximate normalization gives the equivalent flux in electrons per $\text{cm}^2/\text{sr}/\text{ev}/\text{sec}$. The channeltron efficiencies were obtained from Archuleter and DeForest (1971). For $1 \text{ keV} \leq E \leq 50 \text{ MeV}$, $\epsilon = 1.0 - 2.0/(3.0 + 6.5/(E - 0.5) + 30.0/(E - 0.5)^3)$ where E is expressed in keV. For $10 \text{ ev} \leq E \leq 70 \text{ eV}$ ϵ was taken to be

$$\epsilon = 0.10 E^{0.515} \text{ (E in ev)}$$

Note that the midpoint energies in Figures 10 and 11 are not the same as in Table 2, which are the final calibrated values. This does not affect H, however, which is energy-independent. The stated errors in Table 2 for the various energy channels are a best estimate from electronic and experimental uncertainties.

TABLE 1

Measured Energy and Angular Resolutions With a
Monoenergetic and Unidirectional Electron Beam

	<u>Channels 1-8</u>	<u>Channels 9-16</u>
$\Delta\alpha$	$1.6 \pm 0.2^\circ$	$3.7 \pm 0.7^\circ$
$\Delta\beta$	$8.0 \pm 0.8^\circ$	$4.75 \pm 0.08^\circ$
$\Delta E/E(R_0)$	$4.0 \pm 0.4\%$	$7.2 \pm 0.4\%$
G (Aperture)	$6.22 \times 10^{-2} \text{ cm}^2\text{-sr}$	$3.929 \times 10^{-3} \text{ cm}^2\text{-sr}$

TABLE 2

SSJ/3 Normalizations

$$H = 1.30 \times 10^{-4} \text{ cm}^2\text{-sr}$$

Channel Number	Center Energy (eV)	Channeltron Efficiency ϵ	G = HE ϵ Normalization (G) HE ϵ (cm ² -sr-eV)
1	20,000 \pm 3%	0.405	1.05x10 ⁰
2	13,700 \pm 3%	0.43	7.66x10 ⁻¹
3	8,990 \pm 3%	0.48	5.59x10 ⁻¹
4	5,500 \pm 3%	0.56	4.00x10 ⁻¹
5	3,790 \pm 3%	0.66	3.25x10 ⁻¹
6	2,290 \pm 3%	0.83	2.47x10 ⁻¹
7	1,590 \pm 5%	0.94	1.94x10 ⁻¹
8	1,060 \pm 6%	0.99	1.36x10 ⁻¹

$$H = 4.3 \times 10^{-5} \text{ cm}^2\text{-sr}$$

9	1,045 \pm 3%	1.00	4.49x10 ⁻²
10	661 \pm 3%	1.00	2.84x10 ⁻²
11	434 \pm 3%	1.00	1.86x10 ⁻²
12	264 \pm 3%	1.00	1.13x10 ⁻²
13	183 \pm 3%	1.00	7.86x10 ⁻³
14	110 \pm 3%	1.00	4.73x10 ⁻³
15	77 \pm 5%	1.00	3.31x10 ⁻³
16	51 \pm 6%	.76	1.67x10 ⁻³

ACKNOWLEDGEMENTS

We would like to express our appreciation to Dr. Davis Nelson of Aerospace Corporation who substantially contributed to many of the design features. In addition we would like to express our gratitude to the Space Physics Laboratory at Aerospace Corporation for the use of their calibration facilities.

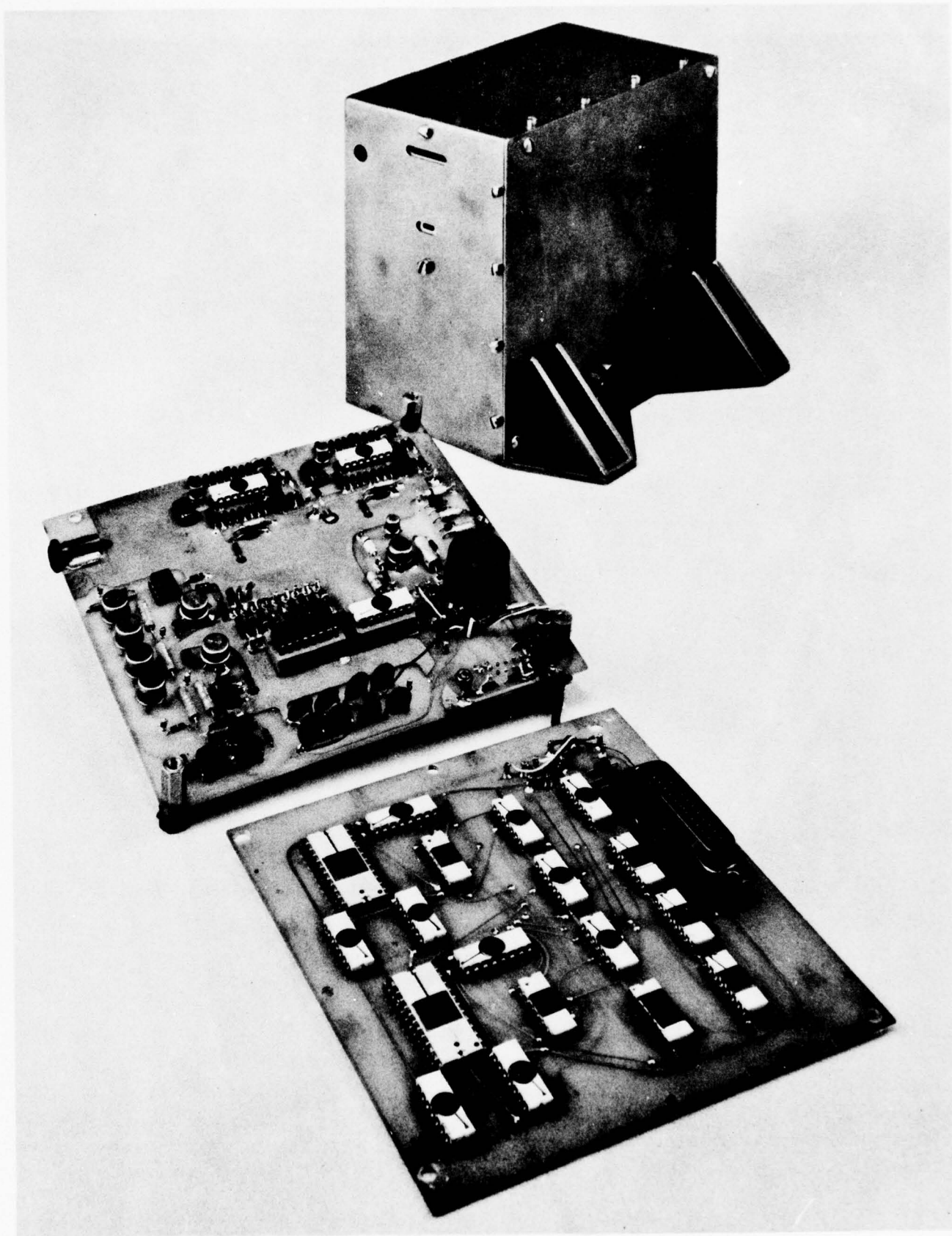


Fig. 1

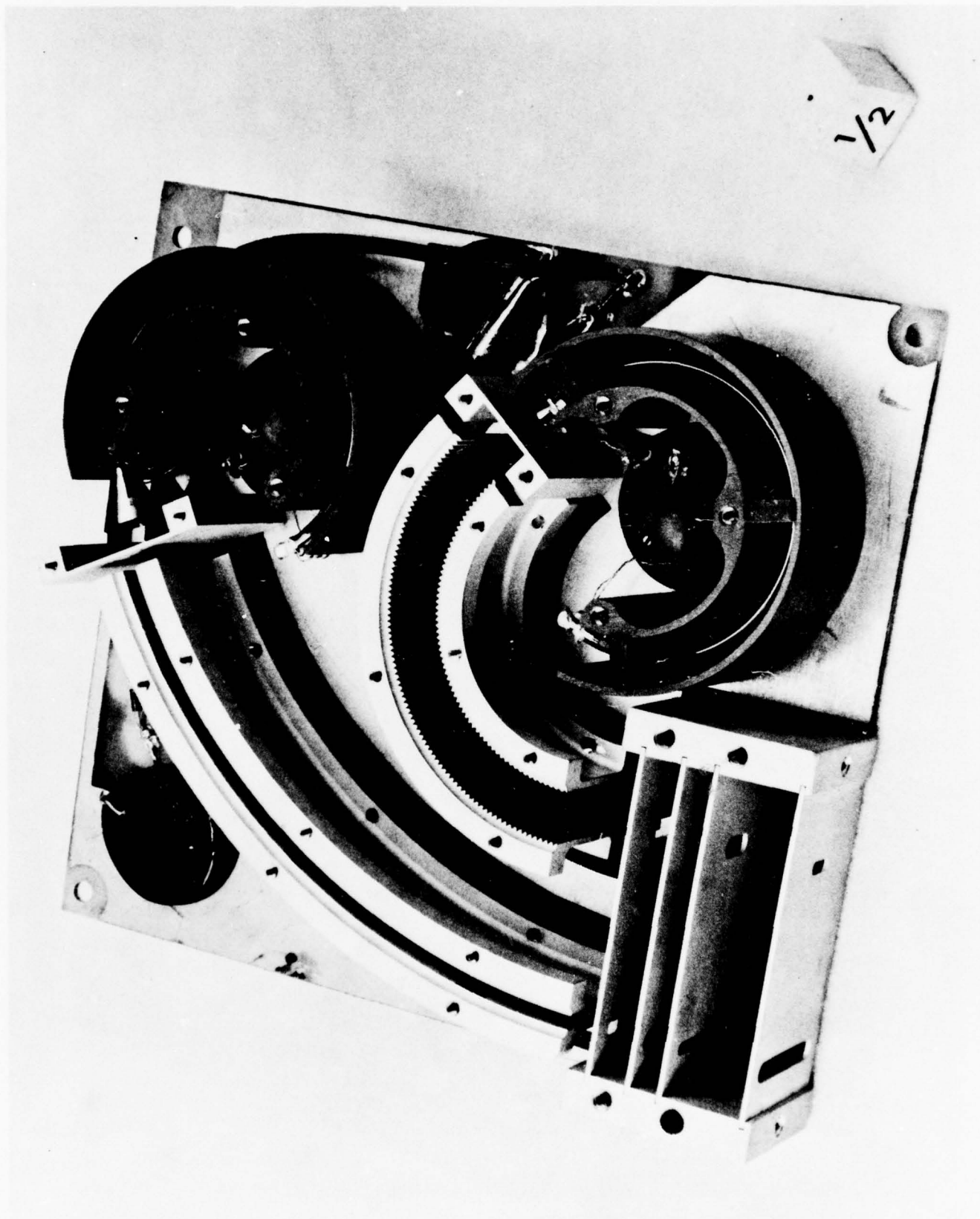


Fig. 2

SSJ/3 ESA ASSEMBLY

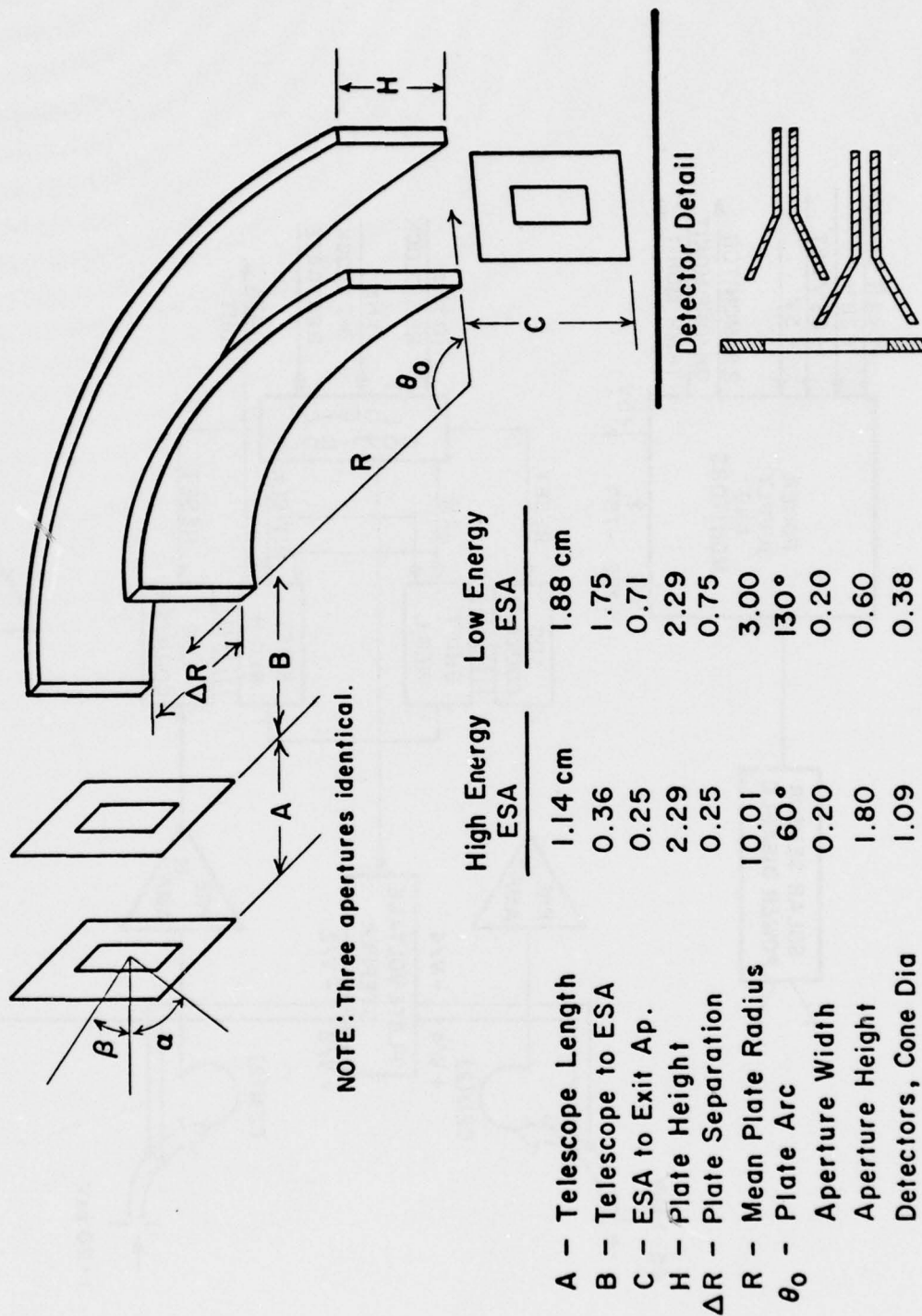


Fig. 3

SSJ/3 BLOCK DIAGRAM

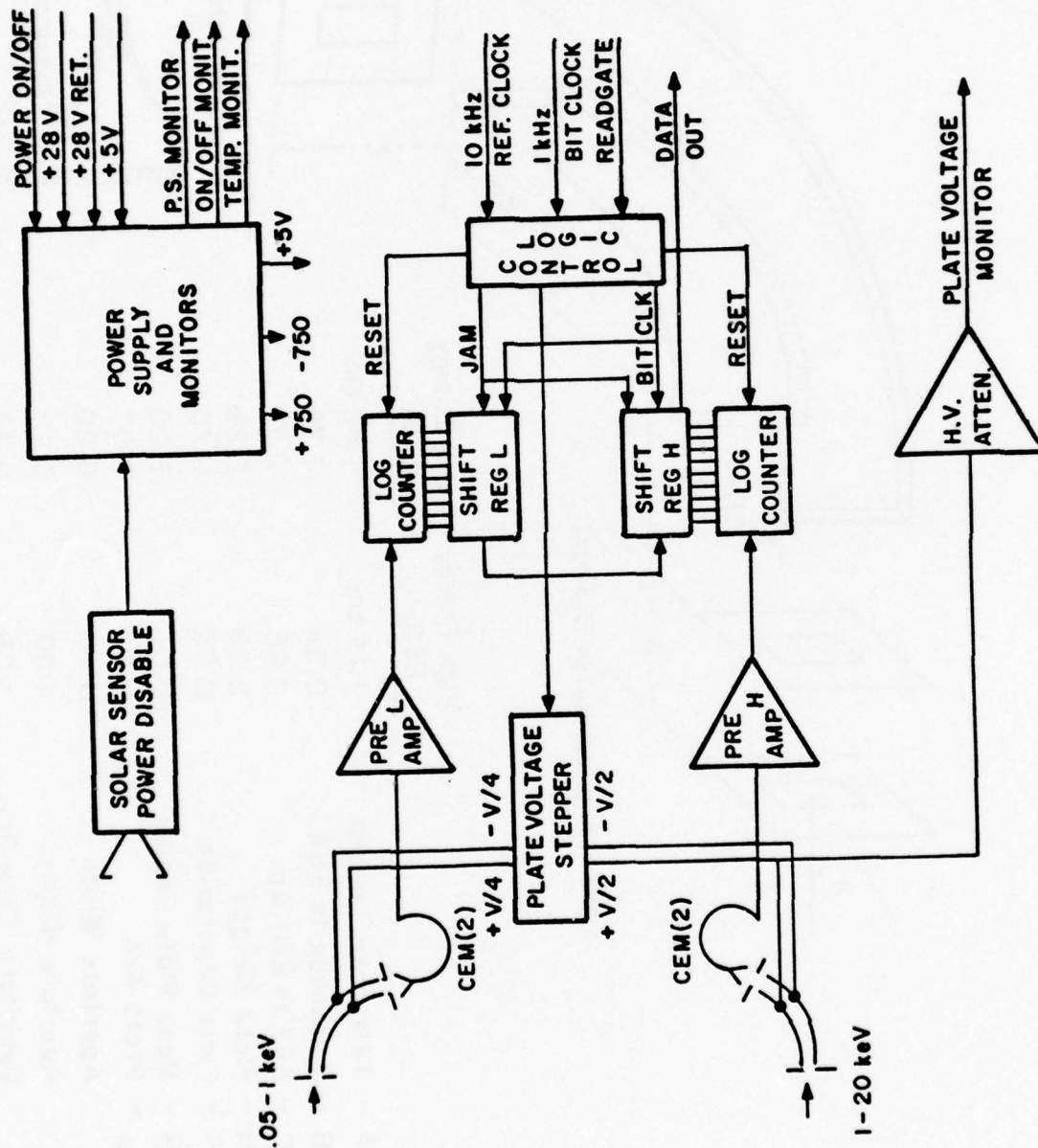


Fig. 4

ENERGY RESPONSE NORMALLY INCIDENT AND MONOENERGETIC BEAM

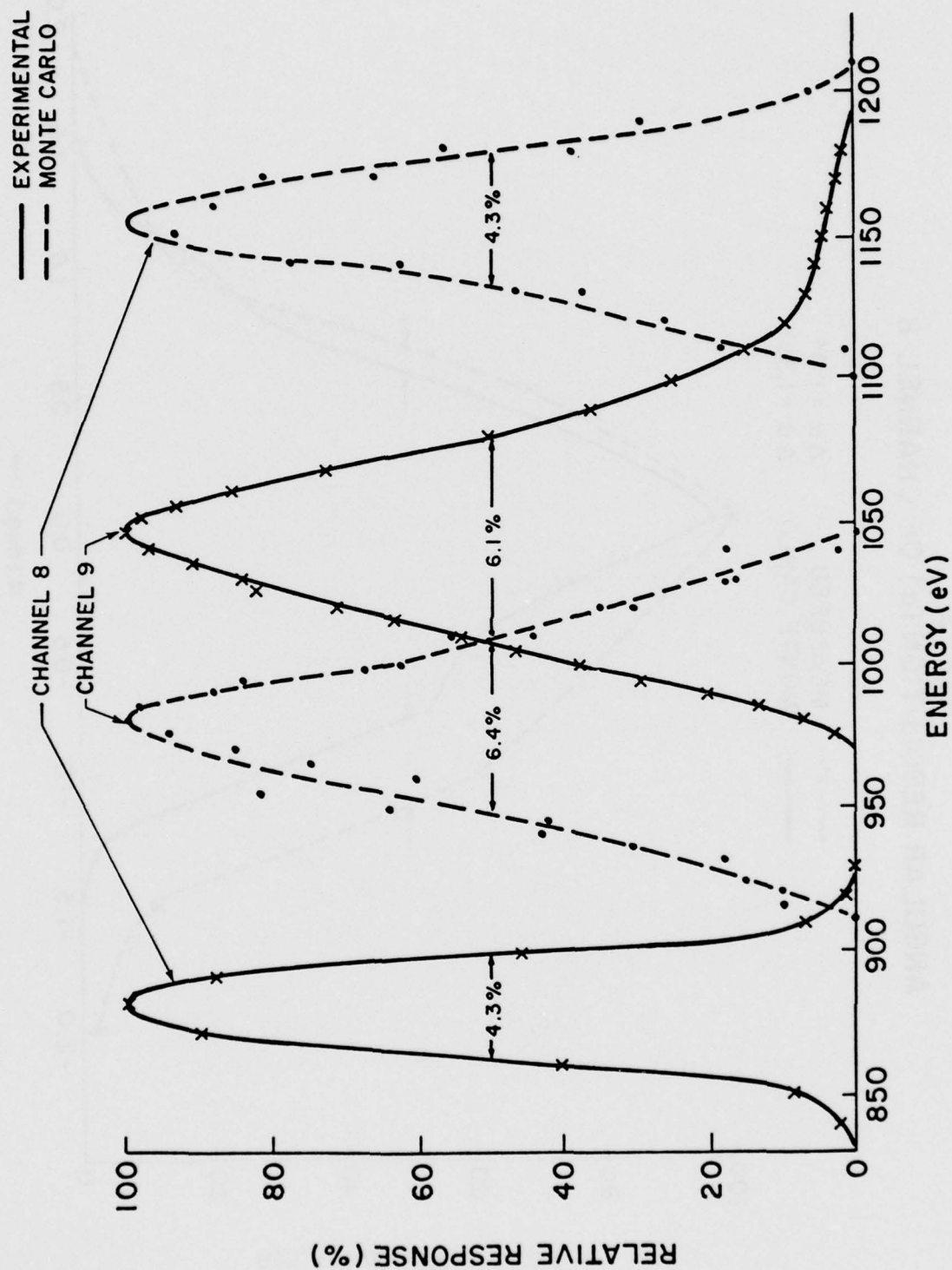


Fig. 5

SSJ/3 ANGULAR RESOLUTION (α) OF CHANNEL 8

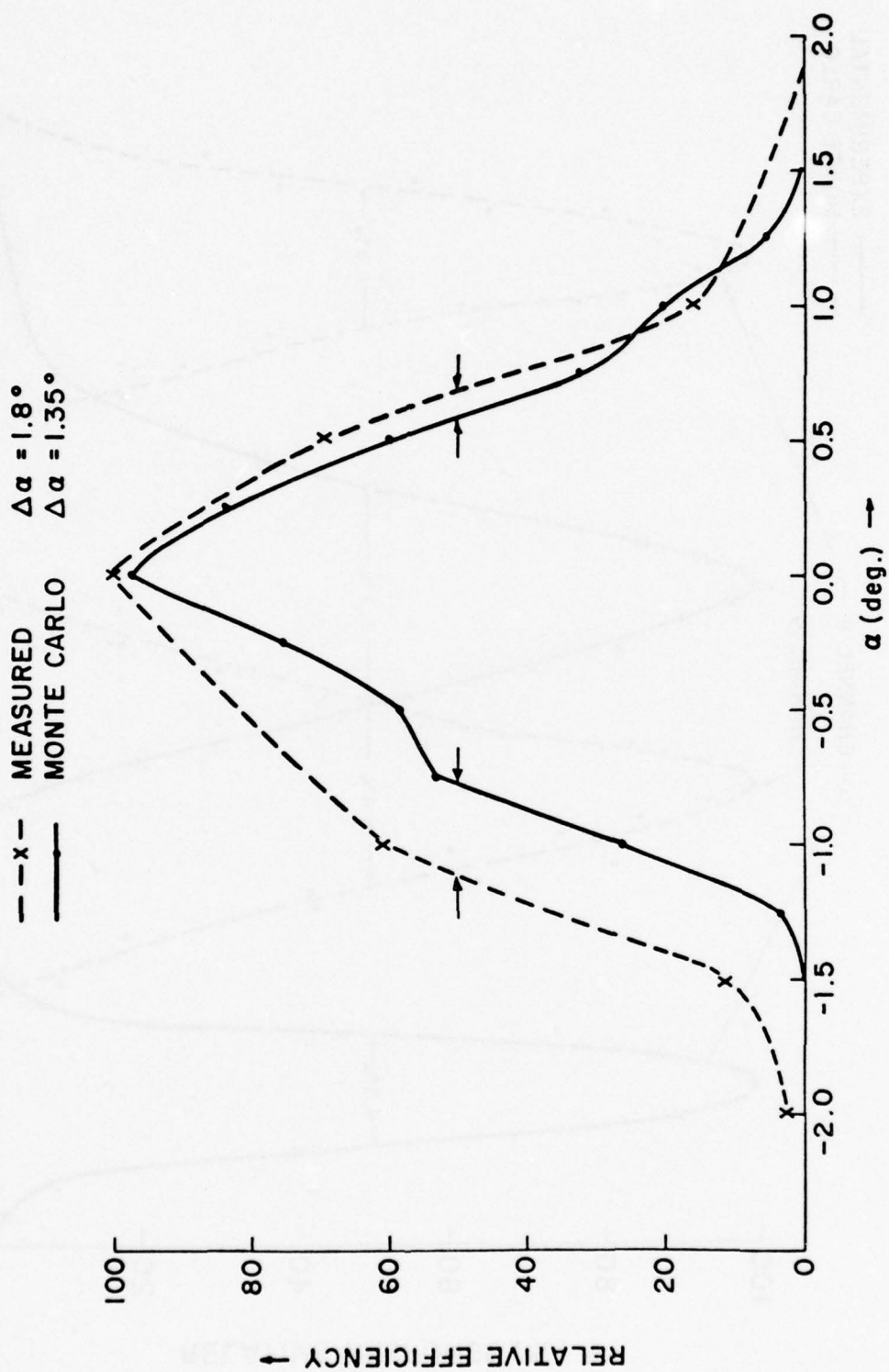


Fig. 6

ANGULAR RESOLUTION (α) OF SSJ/3 ENERGY CHANNEL 9

MONTE CARLO
DATA

$\Delta\alpha = 4.5^\circ$ MONTE CARLO
 $\Delta\alpha = 3.7^\circ \pm 0.7$ MEASURED

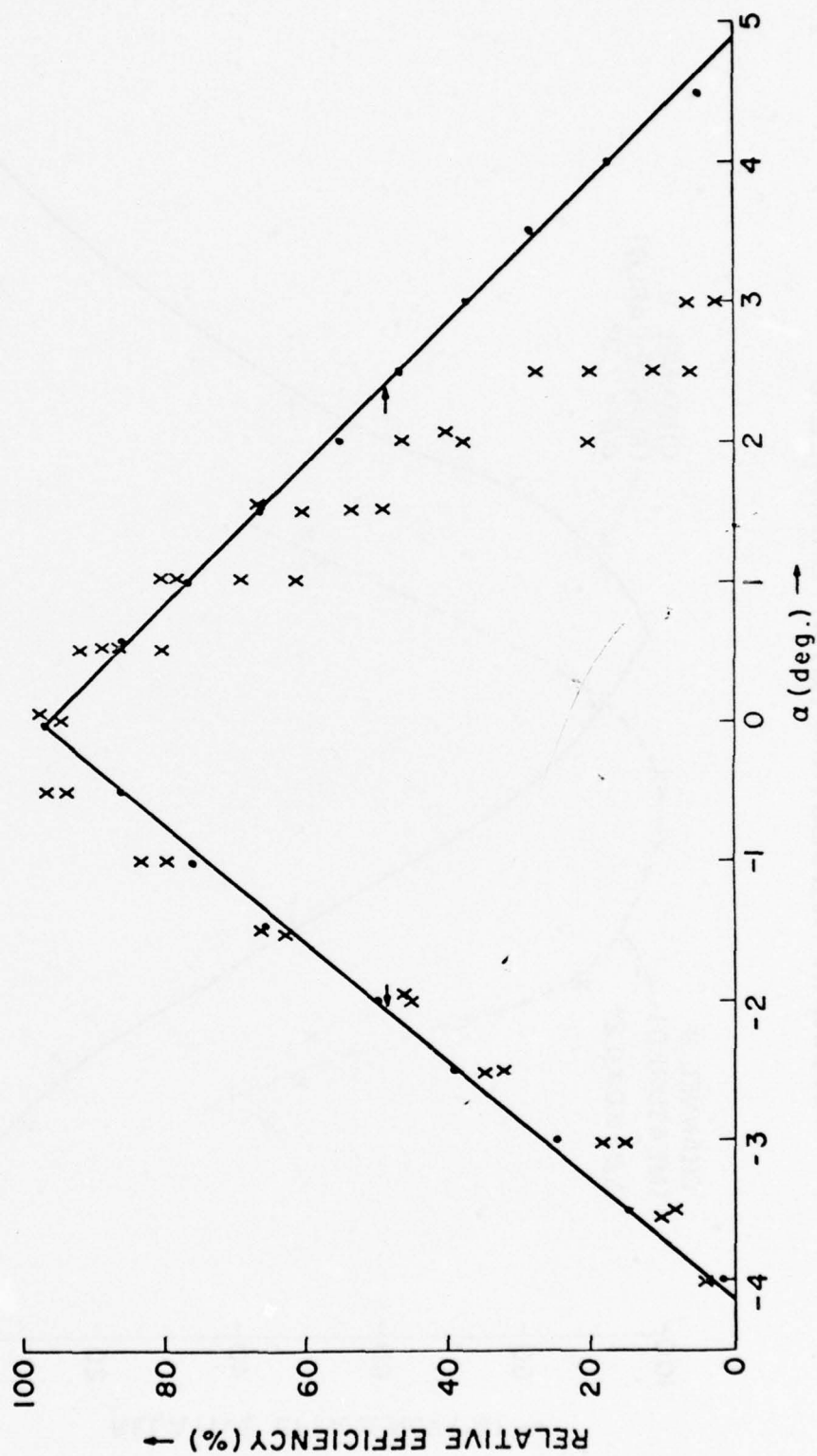


Fig. 7

SSJ / 3
ANGULAR RESOLUTION (β) OF CHANNEL 8

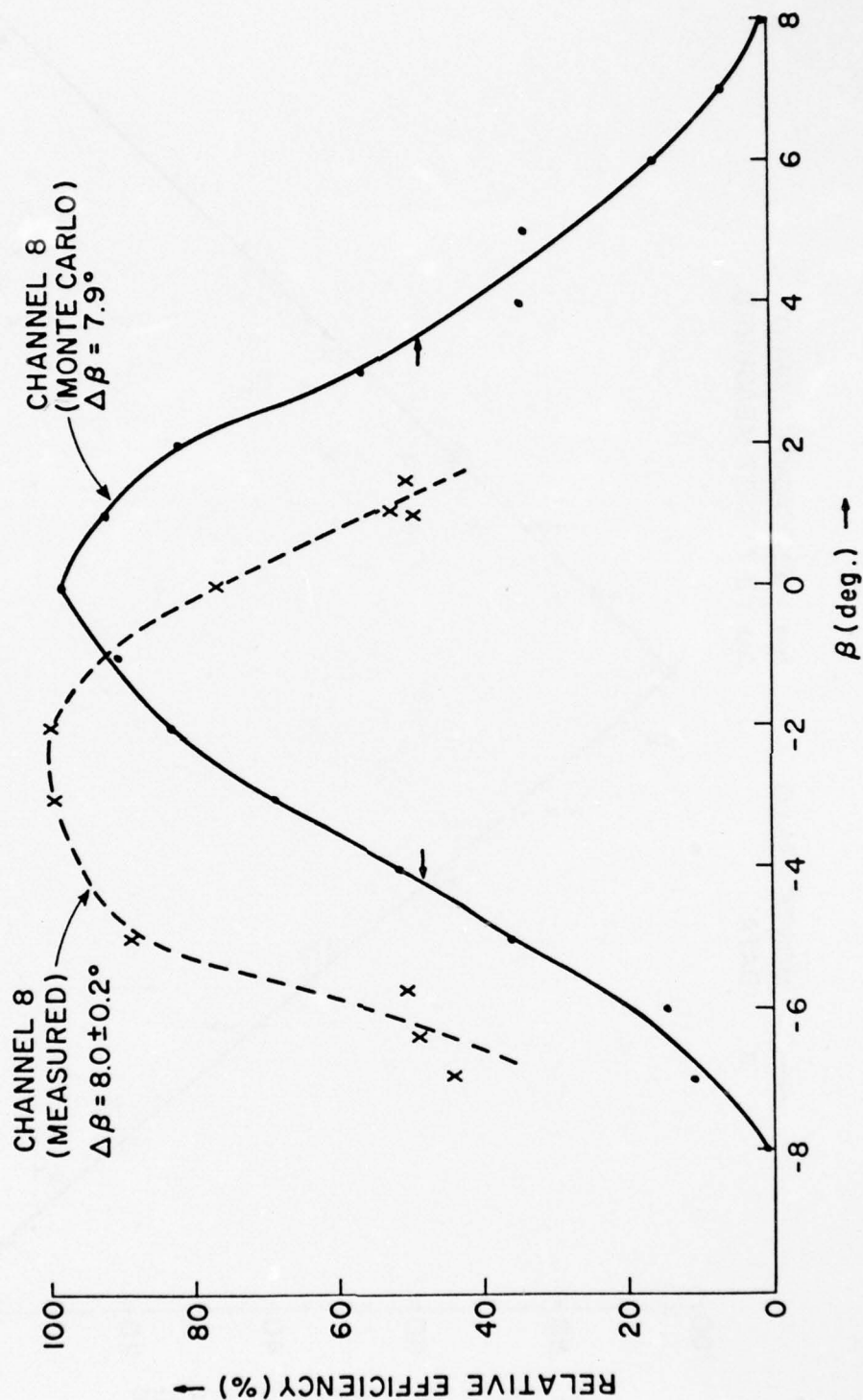


Fig. 8

ANGULAR RESOLUTION (β) OF SSJ/3 ENERGY CHANNEL 9

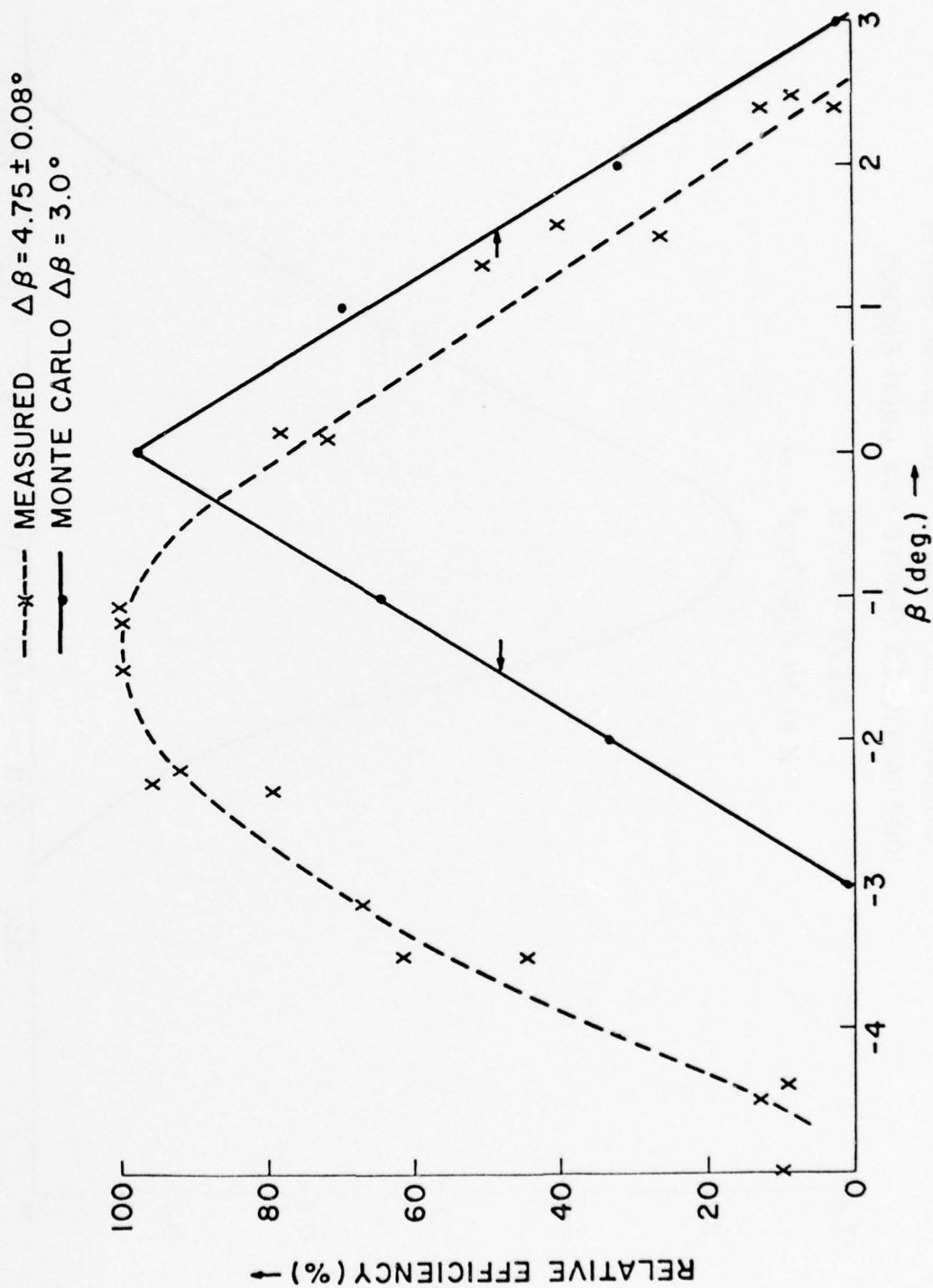


Fig. 9

ENERGY RESPONSE - ISOTROPIC INCIDENT FLUX
CHANNEL 8 - MONTE CARLO PROGRAM
1000 PARTICLES TRACED FOR EACH ENERGY

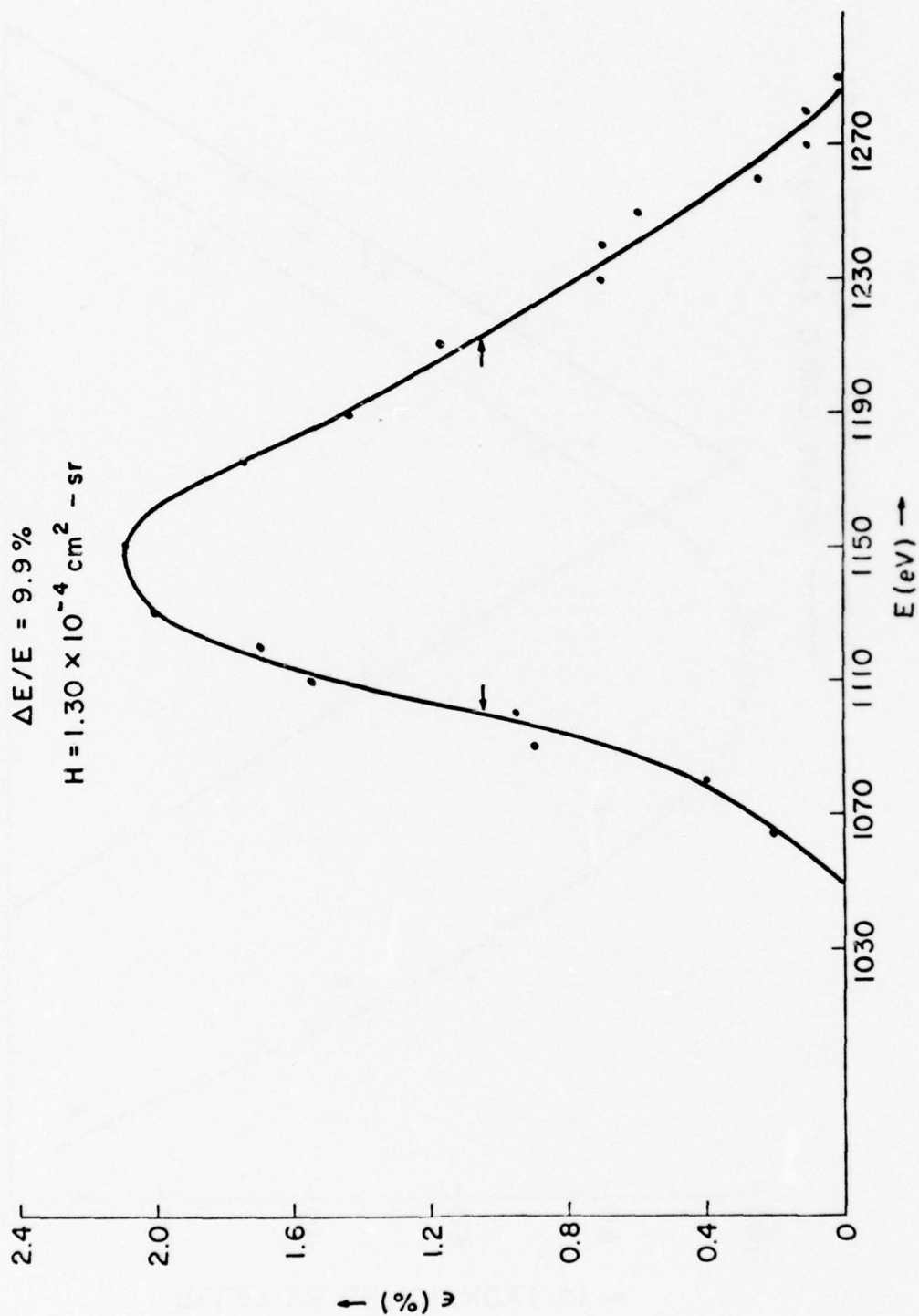


Fig. 10

ENERGY RESPONSE - ISOTROPIC INCIDENT FLUX CHANNEL 9 - MONTE CARLO PROGRAM

1000 PARTICLES TRACED FOR EACH ENERGY

$$\Delta E/E = 9.2\%$$

$$H = 4.3 \times 10^{-5} \text{ cm}^2 - \text{sr}$$

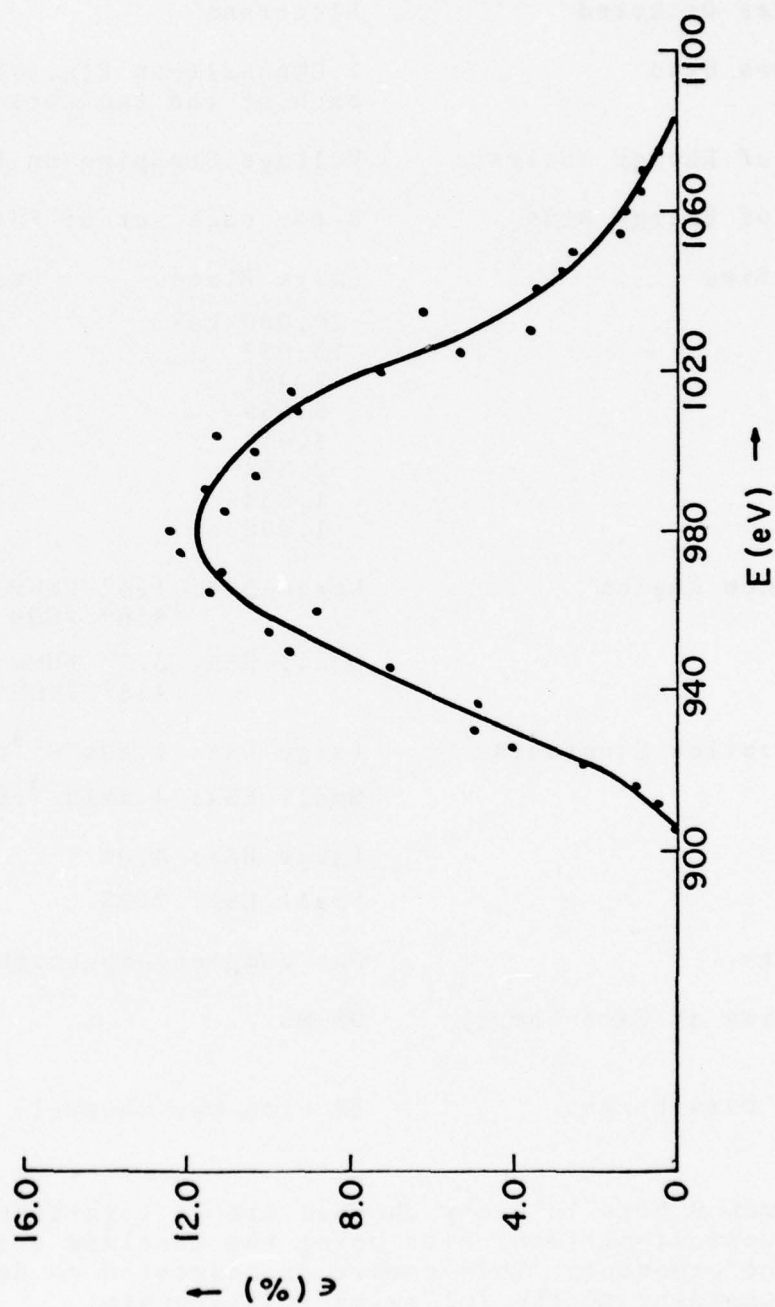


Fig. 11

APPENDIX A
ELECTROSTATIC ANALYZER (ESA)
SSJ/3 OR GFE3

Summary of Characteristics

Particles Detected	Electrons	
Detectors Used	2 Channeltron Electron Multipliers for each of the two sets of ESA plates	
Method of Energy Analysis	Voltage Stepping on ESA plates	
Number of Energy Bins	8 for each set of ESA plates; total of 16	
Energy Bins	Large Plates	Small Plates
	20.000 keV	1.000 keV
	13.037	.652
	8.498	.425
	5.539	.277
	3.611	.181
	2.354	.118
	1.534	.077
	1.000	.050
Acceptance Angles	Large ESA: 1.6° FWHM across the apertures 8.0° FWHM along the apertures Small ESA: 3.7° FWHM across the apertures 4.8° FWHM along the apertures	
Normalization Constants	Large ESA: $1.30 \times 10^{-4} \text{ cm}^2\text{-ster.}$ Small ESA: $4.3 \times 10^{-3} \text{ cm}^2\text{-ster.}$	
$\frac{\Delta E}{E}$	Large ESA: 4.0% Small ESA: 7.2%	
Data Rate	One complete Spectrum per second	
Dwell Time at Each Energy Level	98 ms.	
Digital Data Format	(9 bits per channel) x (16 channels) = 144 bits	

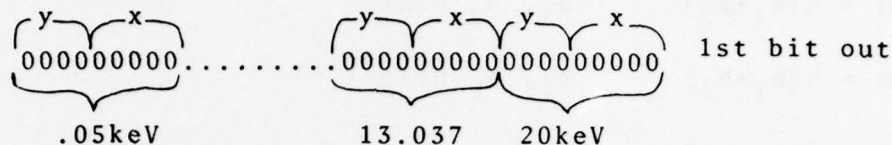
Note: Each 9 bits in every channel are in logarithmic form, the five least significant bits being the mantissa and the remaining four the exponent. This number is converted to decimal form according to the following relationship:

$$N = 2^Y(x+32) - 33$$

where; 0000000000^{←LSB}
 y x

Data Readout

The first bit to be read out is the least significant bit (LSB) of the highest channel followed by the next to the highest one etc., i.e.:



[.....144 bits.....]

read out in one group
 at the end of each second

Analog Monitors

Plate voltages: 5.0 volts to .25v

Power supply : 2.5v

Temperature : 2.5v at room temperature

Size

5.50in X 3.39in X 5.10in

Weight

3.046 lbs

Power Dissipation

.125 watts

APPENDIX B

The G-factor for a rectangular shaped collimator can be calculated exactly (Rothwell and Moomey, 1972).

With the front and rear apertures having the dimensions (a_1, b_1) and (a_2, b_2) respectively, one can define

$$\alpha = \frac{1}{2}(a_1 + a_2) \quad a_1, a_2 \text{ width}$$

$$\beta = \frac{1}{2}(b_1 + b_2) \quad b_1, b_2 \text{ height}$$

$$\gamma = \frac{1}{2}(a_1 - a_2)$$

$$\delta = \frac{1}{2}(b_1 - b_2)$$

If the collimator has a length L then

$$G = L^2 \ln \left[\frac{L^2 + \alpha^2 + \delta^2}{L^2 + \alpha^2 + \beta^2} \cdot \frac{L^2 + \gamma^2 + \beta^2}{L^2 + \gamma^2 + \delta^2} \right] \\ + F(\alpha, \beta) + F(\gamma, \delta) - F(\alpha, \delta) - F(\gamma, \beta)$$

where $F(\alpha, \beta) = F(\alpha, \beta) + F(\beta, \alpha)$

$$F(\alpha, \beta) = 2\beta(L^2 + \alpha^2)^{\frac{1}{2}} \tan^{-1} \left[\frac{\beta}{(L^2 + \alpha^2)^{\frac{1}{2}}} \right]$$

This expression is consistent with that given by Willis and Thomas (1972) and by Sullivan (1971) (with a corrected typographical error).

APPENDIX C

Listing of computer code that was used for the Monte-Carlo computations.

```

PROGRAM ESAPLTS(INFUT,OUTPUT)
  DIMENSION DAT(24),EFF(200),EE(200),EG(200),AMAT(10,10),S
+UM1(10)
  DIMENSION THH(100),AX(100),THM(100)
  COMMON/F1/EFF,EG,DELE,N5,GINT
  R2(X)=A*X+B
  F(X,Y,AL)=2.0*Y*SQRT(AL**2+X**2)*ATAN(Y/SQRT(AL**2+X**2))
  N5=60
  N7=N5/6
  N9=5
  N11=30
  N12=N11/2
  AMP=1.66E-27
  QOVMP=9.638E 07
  AME=9.1E-31
  QOME=1.7582E 11
  AA=180./3.141596
  CNNTA=0.0
  ELEC=8*ELECTRON
1  CONTINUE
  CALL RANSET(TIME(DUM))
  CNNTA=0.0
C IF II=1 DO BACKGROUND CALCULATION BASE ON "LINE OF SIGHT"
C   IJ.NE. 0, AUTOMATICALLY ASSUMES PARAMETERS FOR L. FRANKS E
+SA
C IJ=2, SIMULATES ELECTRON GUN SCAN OF FRANKS ESA AS SHOWN IN F
+IG. 2 OF
C HIS PAPER
C II=1, DOES LINE OF SIGHT BACKGROUND CALCULATION
C K1=0, NO ELASTIC SCATTERING OFF OF ESA PLATES
C K1=1, MORE THAN 1 SCATTERING OFF OF ESA PLATES PER ELECTRON A
+S DEFINED
C BY K2 (INNER PLATE)
C K1=2, 1/K2X100 PER CENT SCATTERING OFF OF ESA PLATES (INNER P
+LATES)
C K1=3, SCATTERING OFF OF OUTER ESA PLATE AS DEFINED BY K9
C K1=4, SCATTERING OFF OF OUTER ESA PLATE AS DEFINED BY 1/K9X100
C K1=5, SCATTERING OFF OF BOTH PLATES, K2 TIMES INNER PLATE, K9 T
+IMES OFF
C ATE
C K1=6, CATTERING OFF OF BOTH PLATES 1/K2 INNER, 1/K9 TIMES OUTER
+PLATE
C IF IK=0 INCIDENT FLUX IS ISOTROPIC
C IK=1 INCIDENT FLUX AT INCIDENT ANGLE ANGE
C IF IK=2 SCAN IN R-PLANE IN STEPS OF ANGE DEGREES
C IF IK=3 SCAN IN Z-PLANE IN STEPS OF ANGE DEGREES
C NOTE-- IF IK GE 2 INPUT DATA PACK CHANGES
  READ 4,II,IJ,K1,K2,K9,ANGA,ANG2,ANGD,IK,ANGE
4  FORMAT(5I5,3F7.2,I5,F7.2)
  PRINT 1900,IK,ANGE
1900 FORMAT(1X,I5,F7.2)

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IF(K1.EQ.0) K7=1	54
IF(K1.EQ.1) K7=1	55
IF(K1.EQ.2) K7=1	56
IF(K1.EQ.3) K7=2	57
IF(K1.EQ.4) K7=3	58
IF(K1.EQ.5) K7=2	59
IF(K1.EQ.6) K7=3	60
IF(K1.EQ.0) K8=1	61
IF(K1.EQ.1) K8=2	62
IF(K1.EQ.2) K8=3	63
IF(K1.EQ.3) K8=1	64
IF(K1.EQ.4) K8=1	65
IF(K1.EQ.5) K8=2	66
IF(K1.EQ.6) K8=3	67
IF(K1.EQ.7) K7=2	68
IF(K1.EQ.7) K8=3	69
IF(K1.EQ.8) K7=3	70
IF(K1.EQ.8) K8=2	71
READ 3,(DAT(I),I=1,24)	72
3 FORMAT((12A6))	73
READ2,PART,POST	74
2 FORMAT(A8,F8.0)	75
PRINT 5,(DAT(I),I=1,24)	76
5 FORMAT(1F1,12A6/12A6)	77
IF(II.EQ.1) PRINT 10	78
10 FORMAT(1X,*BACKGROUND CALCULATION*)	79
IF(IK.EQ.1) PRINT 12,ANGE	80
12 FORMAT(1X,* CONST. ANGLE SORT,ANGLE=*,F7.2,* DEG.*)	81
IF(PART.EQ.ELEC) AMP=AME	82
IF(PART.EQ.ELEC) GOVMF =-QOME	83
PRINT 6,PART	84
6 FORMAT(1X,*TRACING*,3X,A8/)	85
IF(PART.EQ.ELEC.AND.IJ.NE.0) POST=160.	86
IF(IJ.NE.0) PRINT 16	87
16 FORMAT(1X,* FRANKS ESA *)	88
IF(IJ.EQ.2) PRINT 18	89
18 FORMAT(1X,*ELECTRON GUN FLUX=2.0E 06 ELEC/CMSG/SEC*)	90
IF(K1.NE.0) PRINT 17,K1,K2,K9	91
17 FORMAT(1X,*ELASTIC SCATTERING OFF OF ESA PLATES ,*,	92
+*K1=*,I5,	92
A * K2=*,I5/1X,*IF K1=1 K2 SCATTERINGS PER PART., IFK1=2	93
+ EVERY OT	93
BHER K2 PART. MAY SCATTER*,*K2=*,I5)	94
IF(K1.NE.0) PRINT 21,ANG2	95
IF(K1.NE.0) PRINT 19,ANGA	96
IF(K1.NE.0) PRINT 23,ANGD	97
19 FORMAT(1X,* MAX SCATTERING ANGLE OFF OF OUTER PLATE=*,F7.	98
+2,* DEG*)	98
21 FORMAT(1X,* MAX SCATTERING ANGLE OFF OF INNER PLATE=*,F7.	99
+2,* DEG*)	99
23 FORMAT(1X,*MAX. ANGLE FOR INELASTIC SCATTERING OFF OF OU	100
+TER PLATE	100

A=*,F7.2)	101
C SET-UP APERTURE AND CALCULATE ITS G-FACTOR	102
READ 8,A1,B1,A2,B2,AL1,AL2, AL3,VOLT1,R5	103
6 FORMAT(7F7.3,2F7.3)	104
PRINT 11,A1,B1,A2,B2,AL1,AL2,AL3,VOLT1,R5,POST	105
11 FORMAT(1X,*APERTUREDIMENSIONS*/1X,*FRONT WIDTH=*,F7.3,* C	106
+M*,3X,*FR	106
10NTHT=*,F7.3,* CM*,3X, *BACK WIDTH=*,F7.3,* CM*,3X,*BACK	107
+HT=*,F7.3	107
2,*CM*/1X,*LENGTH OF APER.=*,F7.3,* CM*,3X, *DIST BTWN APE	108
+R AND FLA	108
3TES=*,F7.3,* CM*/1X, *DIST BTWN PLATES AND CHANN.=*,F7.3,*	109
+ CM*,3X,*	109
4BIAS VOLTAGE IN FRONT OF DETECT.=*,F7.1,* VOLTS*/1X,*CHAN	110
+NELTRON R	110
1ADIUS=*,F7.2,* CM*,* POST ACCELERATION=*,F8.0,*VOLTS*/1	111
ALPHA=(A1+A2)/2.0	112
BETA=(B1+B2)/2.0	113
GAM=(A1-A2)/2.0	114
DELTA=(B1-B2)/2.0	115
G1=AL1**2*ALOG((AL1**2+ALPHA**2+DELTA**2)*(AL1**2+GAM**2+	116
+BETA**2)/	116
1(AL1**2+ALPHA**2+BETA**2)/(AL1**2 +GAM**2+DELTA**2))	117
G2=F(ALPHA,BETA,AL1)+F(BETA,ALPHA,AL1)+F(GAM,DELTA,AL1)+F	118
+(DELTA,GAM	118
1M,AL1)-F(ALPHA,DELTA,AL1)-F(DELTA,ALPHA,AL1)-F(GAM,BETA,A	119
+L1)-F(PET	119
2A,GAM,AL1)	120
G=G1+G2	121
PRINT 13,G	122
13 FORMAT(1X,*G-FACTOR FOR APERTURE=*,E10.4,* CMSQ-SR*/1)	123
PRINT 15	124
15 FORMAT(1X,*ESA PLATE DIMENSIONS*)	125
C R2A=RADIUS AT APERTURE	126
C R2B=RADIUS AT EXIT	127
READ 7,R1,R2A,R2B,THE,VOLT,H,TOT,R9	128
7 FORMAT(4F7.3, E10.2, F7.3,E10.4,F7.2)	129
PRINT 9,R1,R2A,R2B,THE,VOLT,H,TOT,R9	130
9 FORMAT(1X,*ZERO POTENTIAL RADIUS=*,F7.3,*CM*,3X,*RADIUS A	131
+T POTENTI	131
1AL V AT APERTURE=*,F7.3,* CM*,3X,*RADIUS AT POTENTIAL V A	132
+T EXIT=*,	132
2F7.3,* CM*/3X,*MAX. ANGLE OF PLATES=*,F7.2,* DEGS*,3X,*VO	133
+LTAGE ON	133
3 PLATES=*,1PE10.2,* VOLTS* /3X,*PLATE HEIGHT=*,0PF7.2,*	134
+CM*, * N	134
4UMBER OF PARTICLES TRACED FOR EACH ENERGY=*,1PE10.2/1X,*D	135
+ISTANCE 0	135
5F CHANNELTRON FROM CENTER OF ESA AXIS=*,1PE10.2,* CM*/1	136
IF(PART.EQ.EIEC) VOLT =-VOLT	137
THE=THE/AA	138

H=H*1.0E-02	139
ANGR=ANGA/AA	140
ANGC=ANG2/AA	141
ANGD=ANG0/AA	142
ANGE=ANGE/AA	143
R1=P1*1.0E-02	144
R2A=R2A*1.0E-02	145
R2B=R2B*1.0E-02	146
P5=R5*1.0E-02	147
R9=R9*1.0E-02	148
B=R2A	149
A= (R2B-R2A)/THE	150
WIG1=AES(R2A-R1)	151
RR=(R1+R2B)/2.0	152
A1=A1*1.0E-02	153
B1=B1*1.0E-02	154
A2=A2*1.0E-02	155
B2=B2*1.0E-02	156
AL1=AL1*1.0E-02	157
AL2=AL2*1.0E-02	158
AL3=AL3*1.0E-02	159
R6=RR-A1/2.0	160
R7=RR-A2/2.0	161
R8=RR+A2/2.0	162
IF(IJ.NE.0) R6=1.24E-01	163
IF(IJ.NE.0) R7=R6	164
IF(IJ.NE.0) R8=R6+A2	165
IF(IJ.EQ.2) THY=-5.0/AA	166
DELY=1.0/AA	167
THW=THY-DELY	168
THX=THE/2.0	169
R3=P2(THX)	170
GO TO 14	171
24 IF(IK.GE.2) READ 26,VOLT	172
IF(IK.GE.2) PRINT 29,VOLT	173
26 FORMAT(1PE10.2)	174
29 FORMAT(1X,* VOLTAGE ON PLATES=*,1PE10.2,* VOLTS*)	175
IF(PART.EQ.ELEC) VOLT =-VOLT	176
14 CONTINUE	177
C USING MKS SYSTEM--ENERGY IN JOULES	178
EE(1)=VOLT/2.0/ALOG(R3/R1)*1.6E-19	179
EE(1)=ABS(EE(1))	180
CONST=QOVMP*VOLT	181
EA=EE(1)/1.6E-19	182
PRINT 31,EA	183
31 FORMAT(1X,*MEAN ENERGY=*,1PE10.2,*EV*)	184
IF(IK.LT.2) GO TO 34	185
THH(1)=-ANGE*N12	186
DO 33 I=1,N11	187
THH(I+1)=THH(I)+ANGE	188
THM(I)=THH(I)*AA	189

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	AX(I)=0.0	190
33	C CONTINUE	191
	THH(N11+1)=THH(N11+1)*AA	192
	GO TO 36	193
34	C CONTINUE	194
	DELE=0.005*EE(1)	195
	EE(1)=0.9*EE(1)	196
	DO 35 K=1,N5	197
	EE(K+1)=EE(K)+DELE	198
35	C CONTINUE	199
36	C CONTINUE	200
	DO 22 J=1,10	201
	DO 22 K=1,10	202
	AMAT(K,J)=0.0	203
22	C CONTINUE	204
25	C CONTINUE	205
	THW=THW+DELY	206
	THW=-4.0/AA	207
	DO 600 K=1,N5	208
	K13=1	209
37	C CONTINUE	210
	K4=0	211
	N4=0	212
	N6=0	213
	K5=0	214
	CNT=0.0	215
	COUNT=0.0	216
	CNTA=0.0	217
	C DELT=TIME INTERVAL FOR EACH STEP	218
	GO TO 40	219
38	IF(IK.GE.2) GO TO 202	220
40	C CONTINUE	221
	K3=0	222
	N3=0	223
	K11=0	224
	K12=0	225
	EX=EE(K)	226
	IF(IK.GE.2) EE(K)=EA*1.6E-19	227
	V=SQRT(2.*EE(K)/AMP)	228
	C PULL OUT DEFOREST CARDS	229
	R=R6+A1*RANF(DUM)	230
	Z1=91*RANF(DUM)	231
	C CHOOSE T1 SUCH THAT FOR J(FLUX) = CONST. T1 IS PICKED SIN(T1*	232
	+COS(T1)	232
	C TIMES,, SIN FOR SOLID ANGLE COS FOR PROJECTED AREA	233
	T1=ACOS(1.0-2.0*RANF(DUM))/2.0	234
	T2=6.2831*RANF(DUM)	235
	IF(IK.EQ.1) T1=ANGE	236
	IF(IK.EQ.1) T2=0.0	237
	IF(IK.EQ.2) T1=THH(K13)	238
	IF(IK.EQ.2) T2=0.0	239

IF(IK.EQ.3) T1=THH(K13)	240
IF(IK.EQ.3) T2=1.5707	241
IF(IJ.EQ.2) T1=ABS(THW)	242
IF(IJ.EQ.2.AND.THW.GE.C.0) T2=180./AA	243
IF(IJ.EQ.2.AND.THW.LT.0.0) T2=0.0	244
V1=0	245
VR=V*SIN(T1)*COS(T2)	246
VTT=V*COS(T1)	247
VZ=V*SIN(T1)*SIN(T2)	248
DT=AL1/VTT	249
R=R+VR*DT	250
Z1=Z1+VZ*DT	251
IF(Z1.GT.B2.OR.Z1.LT.0.0) GO TO 38	252
IF(R.GT.R8.OR.R.LT.R7) GO TO 38	253
CNTA=CNAT+1.0	254
DT=AL2/VTT	255
R=R+VR*DT	256
Z1=Z1+VZ*DT	257
IF(R.GE.R2A.OR.R.LE.R1) GO TO 202	258
ANGM=VTT*R	259
TT1=0.0	260
R3=R2(TT1)	261
CONTT=CONST/ALOG(R3/R1)	262
CONSS=CONST	263
IF(II.EQ.1) CONSS=0.0	264
DELTT=CONTT/(R1+R3)*2	265
DELTT=3.E-01*V/DELTT	266
DELT=3.1416*THE*(R1+R3)/2./V/2.0E 02	267
IF(DELTT.LE.DELT) DELT=DELTT	268
GO TO 20	269
27 CONTINUE	270
IF(K12.GT.0.OR.K11.GT.0) R=R+VR*DELT	271
GOTO 28	272
20 CONTINUE	273
R3=R2(TT1)	274
CONS2=(VTT**2-CONSS/ALOG(R3/R1))/R	275
R=R+VR*DELT+CONS2*DELT**2/2.0	276
VR=VR+CONS2*DELT	277
28 CONTINUE	278
VTT=ANGM/R	279
TT1=TT1+VTT*DELT/R	280
Z1=Z1+DELT*VZ	281
IF(Z1.LE.0.0.OR.Z1.GE.H) GOTO 202	282
IF(TT1.GE.THE) GO TO 400	283
IF(R.GT.R1.AND.R.LT.P3) GO TO 1700	284
GO TO 1800	285
1700 CONTINUE	286
K11=0	287
K12=0	288
GO TO 20	289
1800 CONTINUE	290

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C	K1=1,2-----SCATTER OFF OF INNER SURFACE ONLY	291
C	K1=3,4-----SCATTER OFF OF OUTER SURFACE ONLY	292
	IF(R.GE.R3) GO TO 1300	293
	IF(R.LE.R1) GO TO 1400	294
	GO TO 202	295
1300	CONTINUE	296
	IF(K11.GT.0) GO TO 27	297
	K11=K11+1	298
	GO TO (2(2,1100,1200),K7	299
1400	CONTINUE	300
	IF(K12.GT.0) GO TO 27	301
	K12=K12+1	302
	GO TO (202,900,1000),K8	303
900	CONTINUE	304
	N3=N3+1	305
	IF(N3.GT.K9) GO TO 202	306
	VD=ABS(VR)	307
	THP=ATAN(VD/VTT)	308
	IF(ABS(THP).GT.ANGC) GO TO 1500	309
	VR=-VR	310
	GO TO 27	311
1000	CONTINUE	312
	VD=ABS(VR)	313
	THP=ATAN(VD/VTT)	314
	N6=N6+1	315
	IF(ABS(THP).GT.ANGC) GO TO 1500	316
	VR=-VR	317
	GO TO 201	318
1100	CONTINUE	319
	VD=ABS(VR)	320
	K3=K3+1	321
	IF(K3.GT.K2) GO TO 202	322
	THP= ATAN(VR/VTT)	323
	IF(ABS(THP).GT.ANGC) GO TO 202	324
	IF(ABS(THP).GT.ANGC) GO TO 1600	325
	VR=-VR	326
	GO TO 27	327
1200	CONTINUE	328
	VD=ABS(VR)	329
	K4=K4+1	330
	THP= ATAN(VR/VTT)	331
	IF(ABS(THP).GT.ANGC) GO TO 202	332
	IF(ABS(THP).GT.ANGC) GO TO 1600	333
	VR=-VR	334
	GO TO 200	335
1500	CONTINUE	336
	EX=EX *(1.0-RANF(DUM))**(1.0/1.35)	337
	VA=SQRT(2.0*EX/AMP)	338
	VR=VA*SIN(THP)	339
	VTT=VA*COS(THP)	340
	IF(K8.EQ.3) GO TO 201	341

	GO TO 27	342
1600	CONTINUE	343
	EX=EX*(1.0-RANF(DUM))**(1.0/1.35)	344
	VA=SQRT(2.0*EX/AMP)	345
	VR=-VA*SIN(THP)	346
	VTT=VA*COS(THP)	347
	IF(K7.EQ.3) GO TO 200	348
	GO TO 27	349
200	CONTINUE	350
	IAB=MOD(K4,K2)	351
	IF(IAB.EQ.0) K4=0	352
	K5=K4	353
	IF(IAB.EQ.0) GO TO 27	354
	GO TO 202	355
201	CONTINUE	356
	IAC=MOD(N6,K3)	357
	IF(IAC.EQ.0) N6=0	358
	N4=N6	359
	IF(IAC.EQ.0) GO TO 27	360
202	CONTINUE	361
	CNT=CNT+1	362
	IF(CNT.GE.TOT) GO TO 500	363
	GO TO 40	364
400	CONTINUE	365
C	SET UP MATRIX AT EXIT APERTURE OF FLATES	366
	DO 420 N=1,N9	367
	IF(Z1.GE.(N-1)*H/N9.AND.Z1.LT.N*H/N9) N1=N	368
420	CONTINUE	369
	DO 430 N=1,N9	370
	RRR1=R1+(N-1)*WID1/N9	371
	RRR2=R1+N*WID1/N9	372
	IF(R.GE.RRR1.AND.R.LT.RRR2) N2=N	373
430	CONTINUE	374
	AMAT(N1,N2)=AMAT(N1,N2)+1.0	375
C	DO WE HIT THE CHANNELTRON?	376
	RR=(R1+R2B)/2.0	377
C	FULL DEFOREST ESA CARDS	378
	DIS2=AL3	379
	DT=DIS2/VTT	380
	XX=0.0	381
	VXX=VTT	382
	VT=VOLT1	383
	DTT=0.1*DT	384
	TT=0.0	385
	ACC=QC*MP*VT/DIS2	386
460	CONTINUE	387
	TT=TT+DTT	388
	XX=XX+VXX*DTT-ACC*DTT**2/2.0	389
	VXX=VXX-ACC*DTT	390
C	DOES LOW-ENERGY ELECTRON STOP	391
	IF(VXX.LE.0.0) GO TO 202	392

IF (XX,LT,DIS2) GO TO 460	393
R=F+VP*TT	394
Z1=Z1+VZ*TT	395
IF (IJ,NE,0) R5=1.77E-03	396
IF (IJ,NE,0) R9=-R5	397
R4=ABS(RR-R9-R)	398
C PULL OUT DEFOREST CARDS	399
IF (R,LT,(RR-A2/2.0),OR,R,GT,(RR+A2/2.0)) GO TO 202	400
IF (Z1,GT,B2,OR,Z1,LT,C,0) GO TO 202	401
P4A=SQRT(R4**2+(Z1-B2/2.0-R5)**2)	402
R4B=SQRT(R4**2+(Z1-B2/2.0+R5)**2)	403
IF (R4A,GT,R5,AND,R4B,GT,R5) GO TO 202	404
IF (IK,GE,2) AX(K13)=AX(K13)+1.0	405
COUNT=COUNT+1	406
GO TO 202	407
500 CONTINUE	408
EFF(K)=COUNT/CNT	409
IF (IK,GE,2) AX(K13)=AX(K13)/CNT	410
EG(K)=EE(K)/1.6E-19	411
CNNTA=CNNTA+CNNTA	412
PFINT 5(7,EG(K),CNNTA,CNNTA	413
507 FORMAT(1X,* AT ENERGY = *,1PE10.2,* EV NUMBER OF PA	414
+RTICLES	414
1 THROUGH APERTURE = *,0PF10.2,* RUNNING TOTAL = *,0PF10.2)	415
IF (II,EQ,1) GO TO 630	416
E99=EG(K)/1.0E 03	417
EFI=1.0	418
TEMP=EG(K)	419
EG(K)=EG(K)-VT+POST	420
IF (PART,EQ,ELEC,AND,EG(K),GE,1.0E 03,AND,EG(K),LE,5.0E 0	421
+6)	421
1 EFI=1.0-(2.0/(3.0+6.5/(E99 -0.5)+30./(E99 -0.5)**3))	422
IF (PART,EQ,ELEC,AND,EG(K),GE,1.0E 03,AND,EG(K),LE,70.) EFI=0	423
+ .10*EG(K)	423
1**0.515	424
IF (PART,EQ,ELEC,AND,EG(K),GE,200,AND,IJ,NE,0) EFI=8.199/EG	425
+(K)**0.41	425
A7	426
IF (PART,EQ,ELEC,AND,EG(K),LT,200,AND,IJ,NE,0) EFI=5.9E-04*	427
+EG(K)**1.	427
A38	428
EG(K)=TEMP	429
IF (IK,GE,2) AX(K13)=AX(K13)*EFI	430
IF (IK,GE,2) GO TO 440	431
EFF(K)=EFF(K)*EFI	432
IF (IJ,EQ,2) EFF(K)=EFF(K)*2.0E 06	433
IF (MCD(K,N7),NE,C) GO TO 440	434
E1=EE(K-N7+1)/1.6E-19	435
E2=EE(K)/1.6E-19	436
AN7=N7	437
DO 435 N=1,N9	438

SUM1(N)=0.0	439
DO 435 I=1,N9	440
SUM1(N)=SUM1(N)+AMAT(I,N)	441
435 CONTINUE	442
AN8=N7*TOT	443
PRINT 433,E1,E2,((AMAT(N1,N2),N2=1,N9),N1=1,N9),(SUM1(N),	444
+N=1,N9),	444
1AN8	445
433 FORMAT(1X,*EFFICIENCY MATRIX FOR EXIT APERTURE OF ESA FLA	446
+TES FRM	446
1ENERGY=*,1PE10.2,*EV*,*TO*,1PE10.2,*EV*/0P5F10.2/5F10.2/5	447
+F10.2/5F1	447
Z0.2/5F10.2/1X,*TOTALS*/5F10.2,*PARTICLES TRACED=*,1PE10.2	448
+//)	448
DO 438 I=1,10	449
DO 438 N=1,10	450
AMAT(I,N)=0.0	451
438 CONTINUE	452
440 CONTINUE	453
IF(IK.GE.2) K13=K13+1	454
IF(IK.GE.2.AND.K13.LT.N11) GO TO 37	455
IF(IK.GE.2) GO TO 610	456
GO TO 600	457
600 CONTINUE	458
CALL SIMP	459
610 CONTINUE	460
IF(IK.EQ.3) PRINT 613	461
613 FORMAT(1X,*ANGULAR SCAN IN Z-PLANE*)	462
IF(IK.EQ.2) PRINT 609	463
609 FORMAT(1X,*ANGULAR SCAN IN R-PLANE*)	464
IF(IK.GE.2) PRINT 611, (THM(K),AX(K),K=1,N11)	465
611 FORMAT((1P12E10.2))	466
IF(IK.GE.2) GO TO 24	467
630 CONTINUE	468
THR=THW*AA	469
IF(IJ.EQ.2) PRINT 740,THR	470
740 FORMAT(1X,*ELECTRONS FROM GUN INCIDENT ON APERTURE AT AN	471
+ANGLE OF	471
740 A *,F7.2,* DEG*)	472
PRINT 51	473
51 FORMAT(1X,*EFFICIENCY OF CHANNELTRON TO SEE PARTICLES*)	474
PRINT 55,(EG(K),EFF(K),K=1,N5)	475
55 FORMAT(1X,*ENERGY-EFFICIENCY*/(1P10E12.2))	476
G1=G*GINT	477
PRINT 63,GINT,G1	478
63 FORMAT(1X,*INTEGRAL OF CHANN. EFFIC.=*,1PE10.4,* EV*,3X,*	479
+NORMALIZA	479
TION FACTOR FOR ENTIRE ESA=*,1PE10.4,* CMSQ-SR-EV*)	480
HH=G1/EA	481
PRINT 67,HH	482
67 FORMAT(1X,*DEFOREST H-FACTOR=*,1PE10.4,* CMSQ-SR*)	483
GO TO 1	484
END	485

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	SUBROUTINE SIMP	486
	DIMENSION EFF(200),EG(200)	487
	COMMON/F1/EFF,EG,DELE,N5,GINT	488
C	SIMPSON RULE	489
	DEL=DELE/1.6E-19	490
	N6=N5-3	491
	N7=N5-2	492
	SUM1=0.0	493
	DO 10 J=3,N6,2	494
	SUM1=SUM1+EFF(J)	495
10	CONTINUE	496
	SUM2=0.0	497
	DO 20 J=2,N7,2	498
	SUM2=SUM2+EFF(J)	499
20	CONTINUE	500
	GINT=(EFF(1)+EFF(N5-1)+4.0*SUM2+2.0*SUM1)*DEL/3.0	501
	RETURN	502
	END	503

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REFERENCES

- Pantazis, John; Huber, Alan; and Hagan M.P., Design of Electrostatic Analyzer, AFGL-TR-77-0120, 1977.
- Archuleta, R.J. and DeForest, J.E., Efficiency of Channel Electron Multipliers for Electrons of 1-50 keV, Rev. of Sci. Instru., 42, 89-91, 1971.
- Willis, D.M. and Thomas, G.R., Geometric Factor of a Cosmic Ray Detector: Equivalence of Alternative Analytical Derivations, Eldo-Cecles/ESRO-Cess Scient. and Tech. Rev., 4, 101-102, 1972.
- Sullivan, J.D., Geometrical factor and directional response of single and multi-element particle telescopes, Instr. and Methods, 95, 5-11, 1971.
- Rothwell, Paul L., and Moomey, Wayne R., Calibration of a Magnetic Spectrometer Designed to Measure 0.1 -1.0 MeV Electrons in Space, AFCRL-72-0710, 1972.

